ACTS Propagation Terminal Prototype Planning and Design

by

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Abstract

This paper examines the planning and design of a prototype propagation receive terminal for beacon signal at 27 and 20 GHz bands. The developmental plan is discussed first followed by technical design considerations including, a) ACTS system salient features and frequency plan, b) beacon signal parameters and specifications, c) system calculations, and d) terminal hardware design issues.

1. Introduction

The purpose of the Advanced Communications Technology Satellite (ACTS) is to demonstrate the feasibility of Ka-band (20/30 GHz) spectrum for Satellite Communications and to help maintain US leadership in Satellite Communications by incorporating innovative schemes such as advanced TDMA, microwave and baseband switching, onboard regeneration, and adaptive application of coding during rain fade conditions.

The success or failure of ACTS experiment will hinge upon one critical issue that is how accurately one could predict the rain fade statistics, fade dynamics and derive an appropriate algorithm to combat weather vagaries specifically for links with small terminals such as VSATs (Very Small Aperture Terminals) where the power margin is a premium.

Unlike terrestrial links, a satellite link has two elements in the same link such as the up-link and the down-link which may fade simultaneously or individually. Therefore, continuous measurements in the up-link (27 GHz) and in the down-link (20 GHz) have to be carried out to predict the rain attenuation. Furthermore, in addition to finite perturbation in receiver noise temperature, any attenuation process that involves energy absorption is associated with thermal noise emission to maintain thermal equilibrium. Signal absorption due to rain gives rise to an increased system noise temperature [1]. Therefore, in addition to rain attenuation measurements some radiometric measurements have to be carried out simultaneously to assess the

degradation caused by the increased system noise due to rain and finite perturbation in system noise temperature due to fluctuations in the receiving system.

This paper presents an outline of the process involved in generating a working plan for the ACTS propagation study and participation of experimenters and hardware designers to finalize the receive terminal design. It is anticipated that experimenters will be located throughout the rain rate regions for the Continental United States [2] and beyond.

2. Planning

Planning for the ACTS propagation terminal was initiated at the First ACTS Propagation Studies Workshop, November 28-29, 1989. The workshop was convened to develop the ACTS propagation studies program. At the end of two days, the participants delivered a set of recommendations regarding propagation studies and experiments using ACTS. These recommendations addressed a range of topics, from the need for propagation data to the configuration and the number of propagation terminals.

Some of these recommendations are:

- Complete models for the prediction of attenuation statistics in climate regions within the United States that have not been studied.
- Obtain a statistical description of attenuation in about 1 percent of a year regime.
- Obtain information needed for the evaluation of the schemes for attenuation compensation employed in the ACTS program.
- Provide additional data for the design of new mitigation techniques.
- Explore the use of 20 to 30 GHz for the development of new services.

The workshop participants also provided guidelines regarding measurement parameters and requirements. These guidelines require that the terminal should be configured to record the following propagation and meteorological parameters:

- 20-GHz beacon receive signal level
- 27-GHz beacon receive signal level
- 20-GHz radiometric sky noise temperature
- 27-GHz radiometric sky noise temperature
- Point rain rate near the terminal

- Atmospheric temperature at the earth surface, and

- Atmospheric humidity at the earth surface.

Due to the approaching spacecraft launch date and the satellite's short life span, it was strongly suggested that the work on the development of the terminals start without delay. The workshop participants agreed that it would be best to collect propagation data for a minimum of three years, an objective that can be achieved only if the terminal development effort starts immediately.

To respond to the workshop recommendations regarding propagation terminals, we have devised a two-phase plan. In phase 1, a terminal prototype will be developed, and in phase 2, a number of terminals (8 to 10) will be manufactured for distribution to ACTS propagation experimenters. Figure 1 shows our schedule for the terminal development effort. The cost of the prototype has been estimated at $400,000.00, which is jointly funded by the ACTS Project ($300K) and the Propagation Program ($100K). The task will be performed cooperatively by Jet Propulsion Laboratory, Virginia Polytechnic Institute, and Michigan Technology University.

An ACTS propagation receiver terminal will consist of a dual-channel receiver, a dual-channel radiometer, and a data acquisition system. The terminal will also be equipped with meteorological recorders for measuring the point rain rate, and the atmospheric temperature and humidity. Provisions will be provided for an HBR signal output at a convenient receiver I.F. Subsystem. HBR channel power when transmitted for example in a CW mode via the spacecraft steerable antenna will permit propagation measurements outside the CONUS. Therefore, this provision will facilitate experiments in the Arctic and the Tropics.

3. ACTS System Salient Features and Frequency Plan

ACTS uses three different beam connectivities as follows [3]:

- Electronically hopping spot beams for low capacity links

- Fixed spot beams for high capacity links

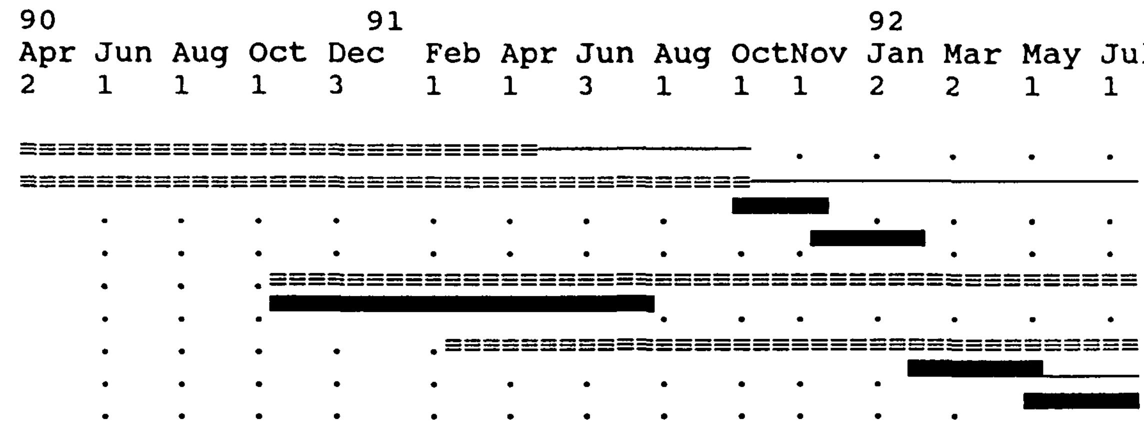
- Mechanically steered spot beam for experiments outside the normal CONUS coverage.

There are two hopping beams; one of these hopping beams can hop to six discrete locations, each encompassing a major metropolitan area, and also to anywhere within a contiguous area called the west sector. The second hopping beam can hop to seven discrete locations and to anywhere within a contiguous area called the east sector. There are three stationary beams, focused on Cleveland, Atlanta, and Tampa.

The half-power beamwidth for both the stationary and the hopping beam is approximately 0.3 degrees. For experimental purposes and to extend the

Schedule Name : ACTS Experimenter's Terminal Development
Responsible : JPL Section 339
As-of Date : 5-Mar-90 Schedule File : C:\TL3\DATA\ACTS00

Task Name	Start Date	Duratn (Mths)
RF Sys. Devel. (20/30)	2-Apr	12
Digital Rcvr. Devel.	2-Apr	17
Integ. Proto.	25-Sep	2
Test Proto.	27-Nov	2
Fab. Expmt. Terminals	9-Oct	20
Long Lead Parts	9-Oct	9
Assemb. & Test	15-Feb	16
Documentation	3-Feb	3
Ship Terminals	6-May	2



Detail Task ===== Summary Task M Milestone
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Figure 1. Schedule for Terminal Development

coverage beyond CONUS, a mechanically steerable antenna with 1.0-degree beamwidth is also incorporated.

ACTS operates in one of the two switching modes. For high-capacity trunk an IF matrix switch is used. For lower-volume traffic such as VSAT networks, a baseband processor provides the switching. In either case, the system access is provided by Time Division Multiple Access (TDMA) with Demand Assignment (DA) managed by the network's master control station.

The three stationary beams use the same frequency, but the Cleveland polarization is orthogonal to that of the other two beams. The two hopping beams also use the same frequency but employ opposite polarization.

ACTS EIRP, G/T and Burst Rate summary is shown below:

Table 1. ACTS EIRP, G/T and Burst Rate Summary

Beam	EIRP (dBw)*		Satellite G/T (dB/K)		Information Rate (Mbps)			
					Uncoded		Coded	
	Max	Min	Max	Min	Up-Link	Dn-Link	Up-Link	Dn-Link
Hopping (#1)	62.9	60	20	17.5	110[a] 27.5[b]	110[a] 110[b]	55[a] 13.75[b]	55[a] 55[b]
Hopping (#2)	63.1	57.6	17.4	14.7	110[a] 27.5[b]	110[a] 110[b]	55[a] 13.75[b]	55[a] 55[b]
Stationary	64.1	57.4	19.8	18.6	220	220	-	-
Steerable (Mechanical)	54.4	-	11.3	-	-	-	-	-

a) Single channel TDMA, b) FDM/TDMA mode (more than one TDMA carrier).

* Existing Ku-band domestic satellite EIRP range is 40-44 dBw. Therefore the excess EIRP of about 17 to 20 dB can be used as fade margins in existing Ku-band VSAT antennas if used in Ka-band.

3. Beacon Signal Parameters and Measured Data

The ACTS System envisions up-link power control during up-link fade and down-link fade compensation will be achieved by a combination of fixed margin plus adaptive application of coding. Beacons are provided at 27 GHz and 20 GHz bands. The up-link beacon is unmodulated whereas there are two beacons

in the down-link, each of these down-link beacons can be modulated by two subcarrier modulated telemetry data channels (PCM and FM). Occasionally, the down-link beacon will be used for ranging also. While ranging the 20 GHz beacon will handle one subcarrier telemetry channel only. The Composite Signal Spectrum including the two subcarrier modulated telemetry channels or the single telemetry channel plus the ranging channel linearly phase modulates the 20 GHz beacon transmitter. It is envisioned that when the spacecraft is on station, only one 20 GHz down-link beacon will be in use while the second beacon will be on a standby mode. Beacon signals are noncoherent.

The principal characteristics [3] of the beacons are shown in Table 2 and the ACTS Frequency Plan is shown in Figure 2.

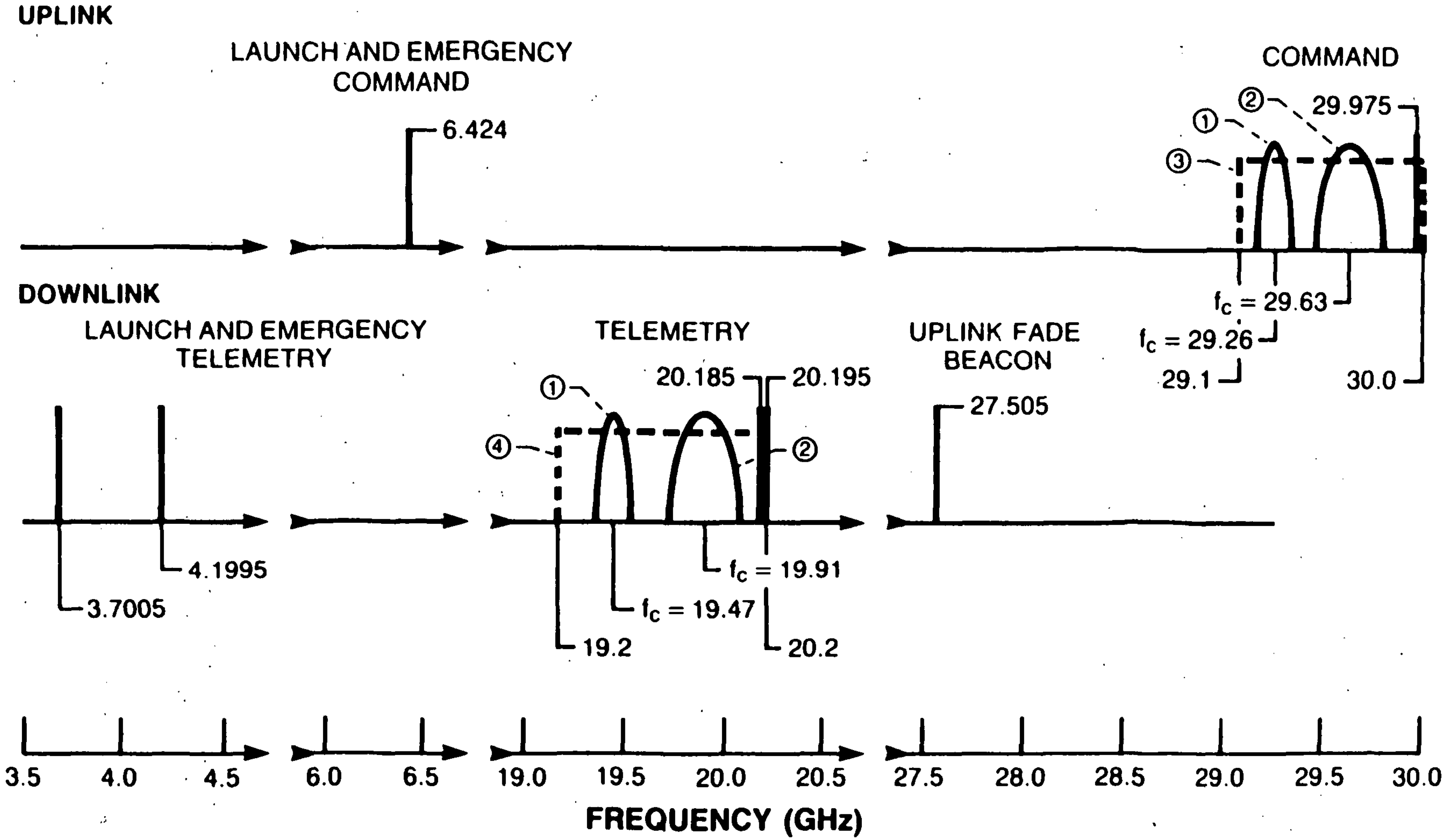
Table 2. Characteristics of the ACTS Beacons

Parameters	27 GHz Beacon	20 GHz Beacon
No. of beacons	1	2
Frequency/(polarization)	27.505 GHz ±0.5 MHz (V)	20·185 GHz ±0.5 MHz (V) 20·195 GHz ±0.5 MHz (H)
Function	Fade Measurement	Telemetry
Modulation	None	Yes (FM & PCM)
Nominal RF output (dBm)	20.0	23
Operating Temperature (°C)	-10 to +55	-10 to +55
Frequency Stability	±10 PPM over 2 years at constant temperature ±1.5 PPM over 24 hours for temperature range -10°C to 55°C	
Output Power Stability	±1.0 dB over 24 hours ±2.09 dB over full mission	
Phase Noise	-49 dBC/Hz @ 50 Hz -80 dBC @ 3000 Hz	-51 dBC/Hz @ 50 Hz -92 dBC/Hz @ 19kHz

Note: Most of the characteristics shown above have been met in actual spacecraft hardware measurements [4].

Measured beacon antenna gain contours [4] are shown in Figures 3, 4 and 5.

ACTS FREQUENCY PLAN



① MAX. BBP (LBR) SIGNAL SPECTRUM, NULL-NULL BW = 165.888 MHz
② MAX. MSM (HBR) SIGNAL SPECTRUM, NULL-NULL BW = 331.77 MHz
③ MAX. BANDWIDTH OF LNR RECEIVER
④ MAX. BANDWIDTH OF TWTA TRANSMITTER

Figure 2.

Ka-Band CR&T Antenna Assembly
V-POL Beacon Pattern—Measured 20.185 GHz

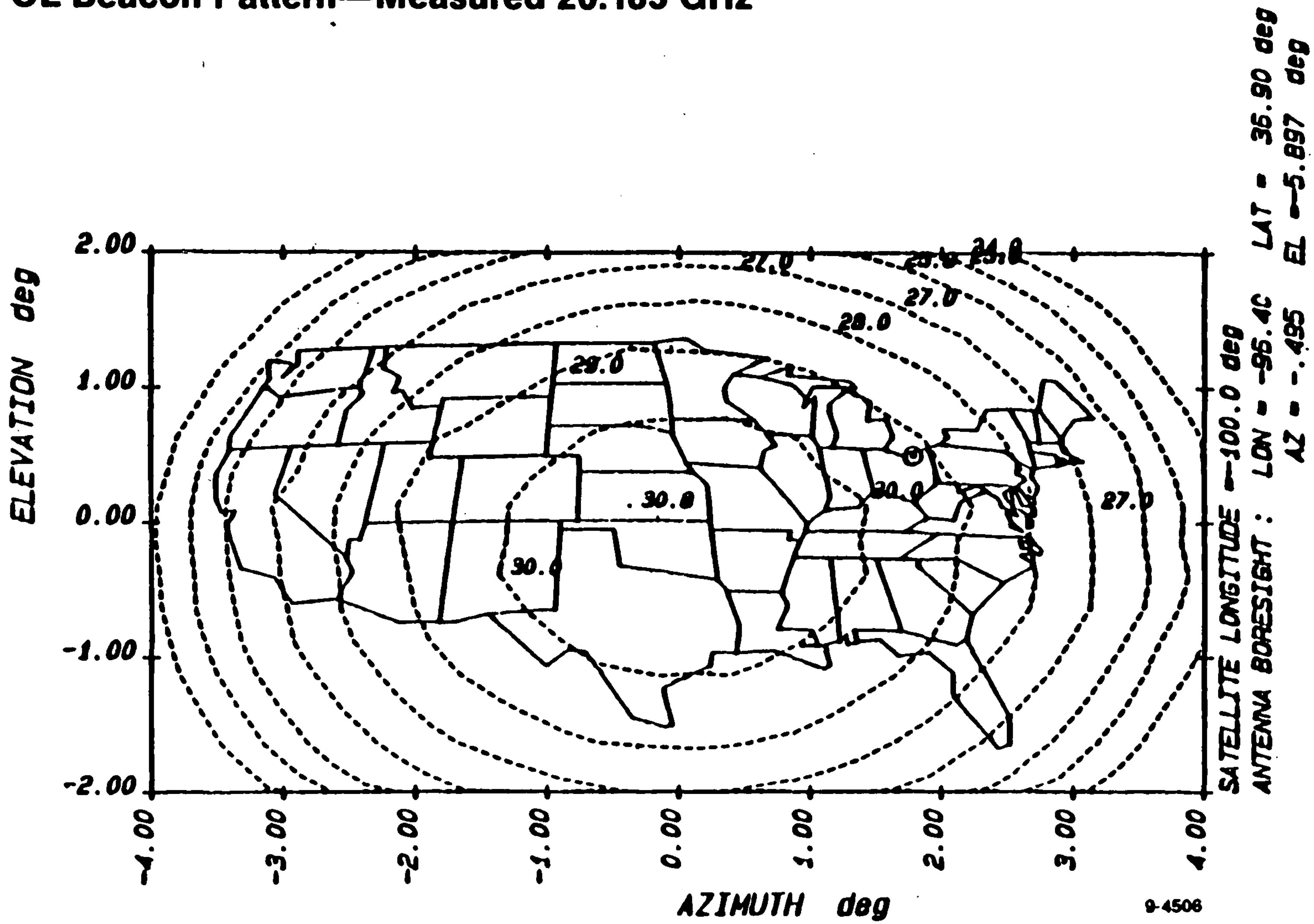


Figure 3.

Ka-Band CR&T Antenna Assembly
H-POL Beacon Pattern—Measured 20.195 GHz

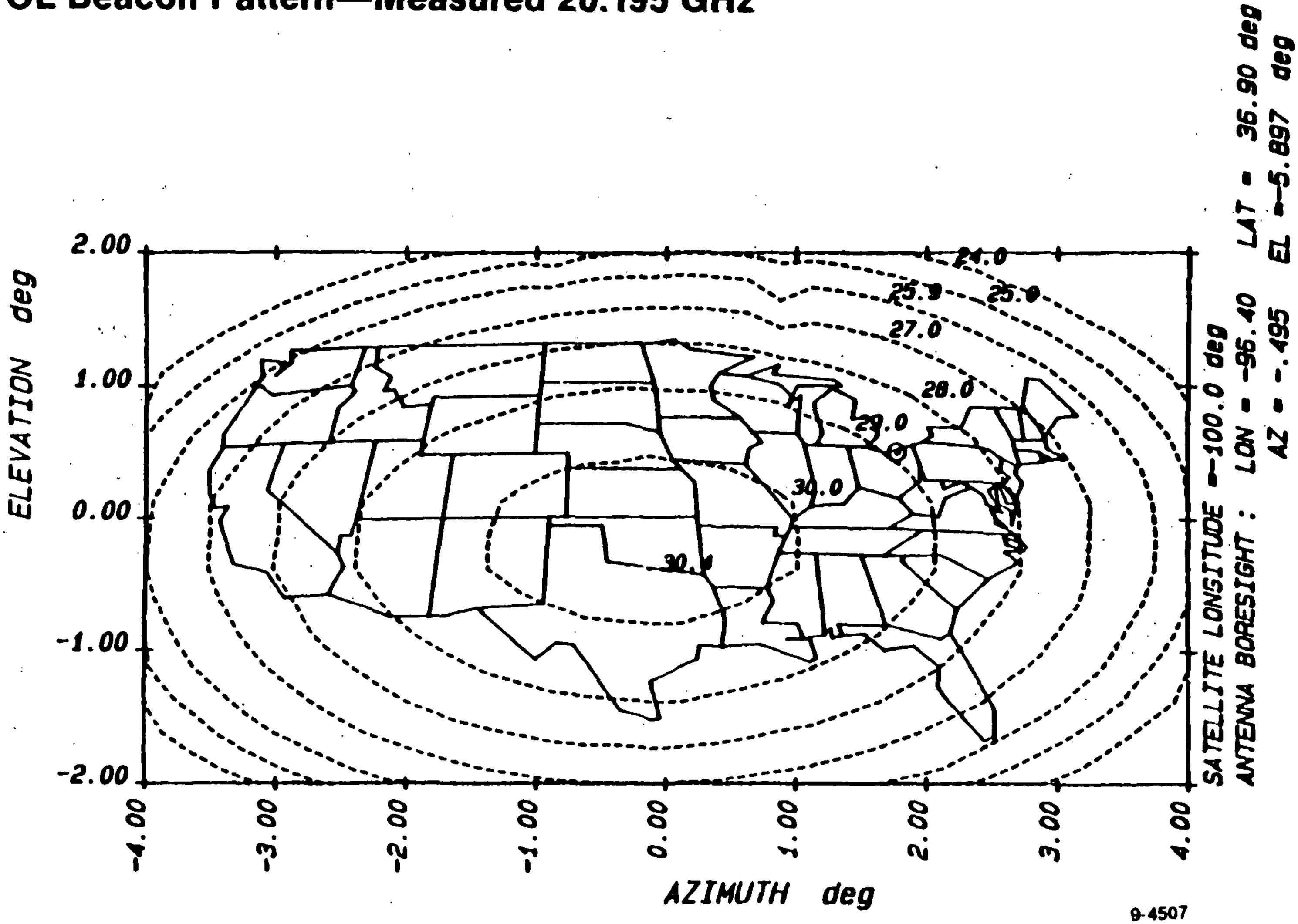


Figure 4.

Ka-Band CR&T Antenna Assembly
Uplink Fade Beacon Pattern—Measured 27.505 GHz V-POL

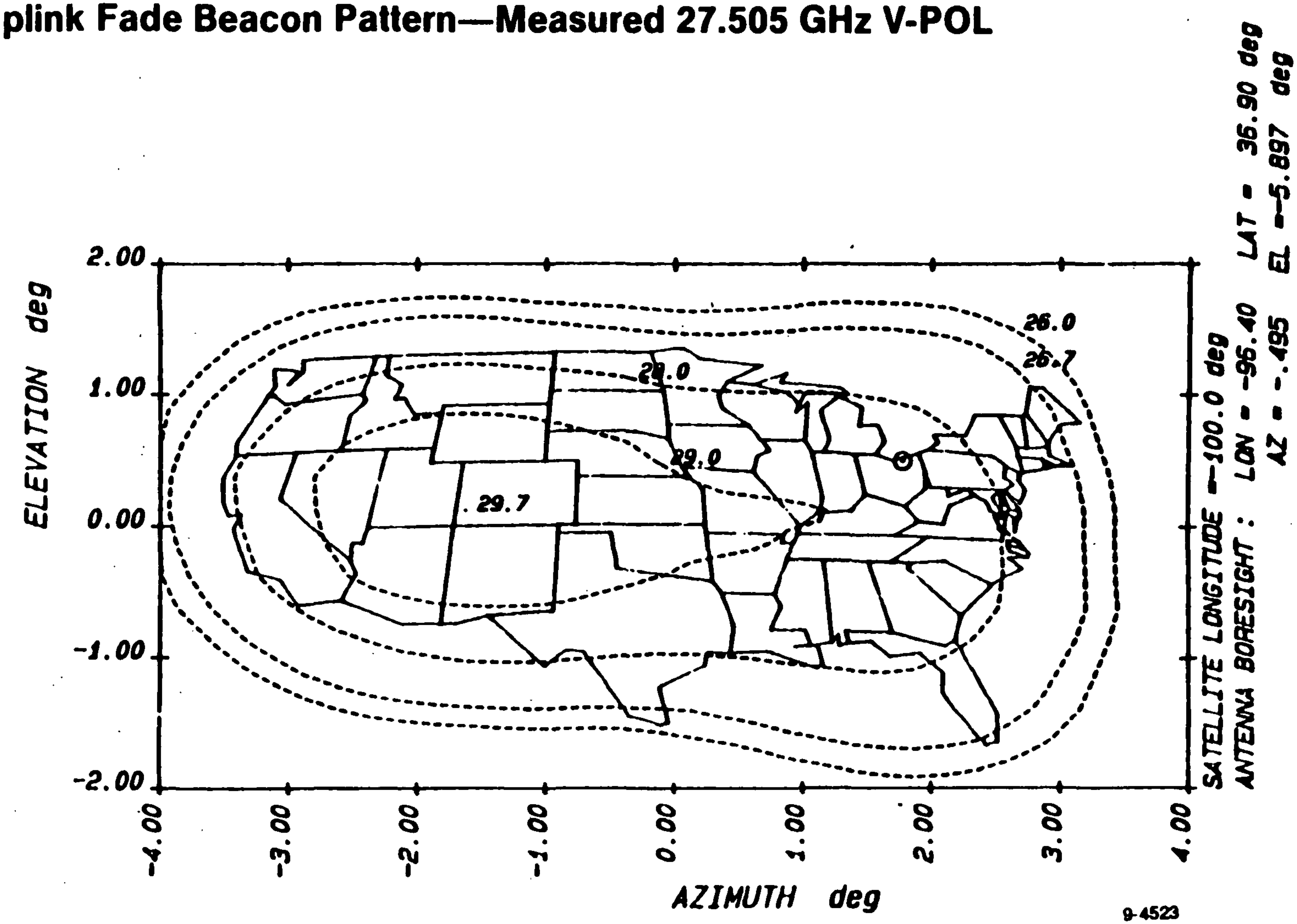


Figure 5.

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4. System Calculations

4.1 Carrier-to-Noise Density

The carrier-to-noise density received on the ground is

$$C/N_o = EIRP \left(\frac{\lambda}{4\pi R}\right)^2 \frac{G}{kT} \frac{1}{L} \qquad (1)$$

where

C/N_o = Carrier-to-noise density
EIRP = Effective Isotropic Radiated Power of the beacon
λ = Wavelength of the beacon
R = Slant range between the satellite and the beacon receive terminal

$\left(\frac{\lambda}{4\pi R}\right)^2$ = Free Space Path Loss (PL) factor

G = Receive Antenna gain factor

k = Boltzmann's Constant (1.38×10^{-23} J/K)

T = Receive System Noise Temperature

L = System Loss factors

Expressing in dB, (1) can be written as

$$\begin{aligned} C/N_o \text{ (dB-Hz)} = {} & \text{EIRP (dBw)} - \text{PL(dB)} + \text{G/T (dB/K)} \\ & + 228.6 \text{ (dBw/K-Hz)} - \text{Losses (dB)} \end{aligned} \qquad (2)$$

4.2 System Losses

The principal sources of dry weather losses are considered as follows:

- Pointing error loss due to receive terminal and satellite antenna boresight to boresight misalignment

- Polarization loss due to rotation of the polarization vector with respect to the reference axis

- Atmospheric, cloud and scintillation loss

- Modulation loss of the carrier due to spreading of the CW carrier energy in modulated sidebands which is dependent on the modulation index chosen.

An estimate of the above losses is shown below:

Table 3. Estimation of System Losses

Source	Losses (dB)	
Frequency Band	27 GHz	20 GHz
Pointing Error (small aperture - no tracking)	1.5	1.2
Polarization Loss (XPD = 25 dB assumed)	0.2	0.2
Atmospheric and Cloud Attenuation	1.8	2.0
Scintillation* [5] (30° elevation)	0.2	0.1
Modulation Loss	-	2.3
Total	3.7	5.8

*Could be much higher for short duration under extreme conditions and at low elevation.

4.3 Receive G/T

The antenna gain-to-noise temperature ratio (G/T) is a trade-off between cost and the dynamic range (margin above threshold) of the receiving system. A common antenna with a dual polarized feed is the desired objective for cost effectiveness and operational considerations.

As a starting point we assume a 1-m dish with Cassegrain or Front Feed. We estimate the antenna efficiency as follows:

Parameter	Losses (dB)	
Frequency Band	27 GHz	20 GHz
Feed horn loss	0.2	0.15
Feed window loss	0.1	0.05
VSWR loss	0.2	0.2
Subreflector spill over loss	0.2	0.2
Main reflector spill over loss	0.1	0.1
Illumination loss	0.2	0.2
Blocking loss	0.6	0.5

Surface tolerance loss	1.0	0.8
Total	2.6	2.2
Expected Antenna Efficiency	55%	60%

The receive noise temperature under rain fade conditions can be written as

$$T_\gamma(a) = \frac{1}{abc}\left[T_s + T_a(a-1)\right] + \frac{T_o}{b}\left[(c-1) + (b-1)\right] + T_L + \frac{T_2}{G_A} \qquad (3a)$$

where

$T_\gamma(a)$ = Receive noise temperature under rain fade
a = Down-link rain attenuation factor
b = Feed loss factor
c = Cloud attenuation factor
T_s = Sky noise temperature
T_a = Rain media temperature = 285°K
T_o = Environmental temperature = 293°K
T_L = LNA noise temperature
T_2 = Post Low-Noise Amplifier Noise Temperature
G_A = LNA gain

For a high-gain LNA, the last term in (3a) can be ignored for all practical purposes. Under dry weather conditions, a = 1 and (3a) simply becomes

$$T_\gamma = \frac{T_S}{bc} + \frac{T_o}{b}\left[(c-1) + (b-1)\right] + T_L + \frac{T_2}{G_A} \qquad (3b)$$

For a given value of T_L, the excess noise temperature due to rain attenuation

$$\Delta T = \{T_\gamma(a) - T_\gamma\} = \left(\frac{a-1}{a}\right)\left(\frac{T_a - T_s}{bc}\right) \qquad (3c)$$

We now estimate noise temperatures contribution at two frequency bands as follows:

Noise Source	Parameter Value	
Frequency Band	27 GHz	20 GHz
Sky (at 30° elevation) (T_s)	30°K	45°K
Rain attenuation (a)	TBD	TBD
Dual Polarized Feed Loss (b)	1 dB	0.8 dB
Cloud attenuation (Slobin Model; Cumulative Distribution >90%)	1.3 dB	1.6 dB
LNA Noise Temperature (T_L)	TBD	TBD
Post LNA Noise (T_2/G_A)	negligible	negligible

Using the above parameters we calculate the excess noise temperature as a function of rain attenuation via (3c) as shown in Figure 6 .

4.4 Radiometers

In order to detect the system noise degradation due to rain attenuation and finite perturbation in the system parameters a radiometric measurement method has to be incorporated. Either Dicke-switched radiometers [6] or total power radiometer with self calibration can be used. The Dicke-switch switches periodically at a high rate between the incoming signal (or noise) with a reference source. By this comparison method at a reasonably high rate the low frequency fluctuations in the receive amplifiers and the active devices can be eliminated. On the other hand, total power radiometers are simple in design where the gain and bandwidth fluctuations of the receiving device need compensation. With temperature control and improved circuit design total power radiometers are becoming popular. The advantage of total power radiometer is that its sensitivity is almost a factor of two better than Dicke radiometer.

For a Dicke radiometer with square wave demodulation the noise temperature sensitivity can be written as

$$\Delta T_{rms} = \frac{2(T_S + T_R)}{\sqrt{B\tau}} \tag{4}$$

T_S = Sky noise temperature
T_R = Receiver noise temperature
B = RF Bandwidth of the receiver
τ = Integration time

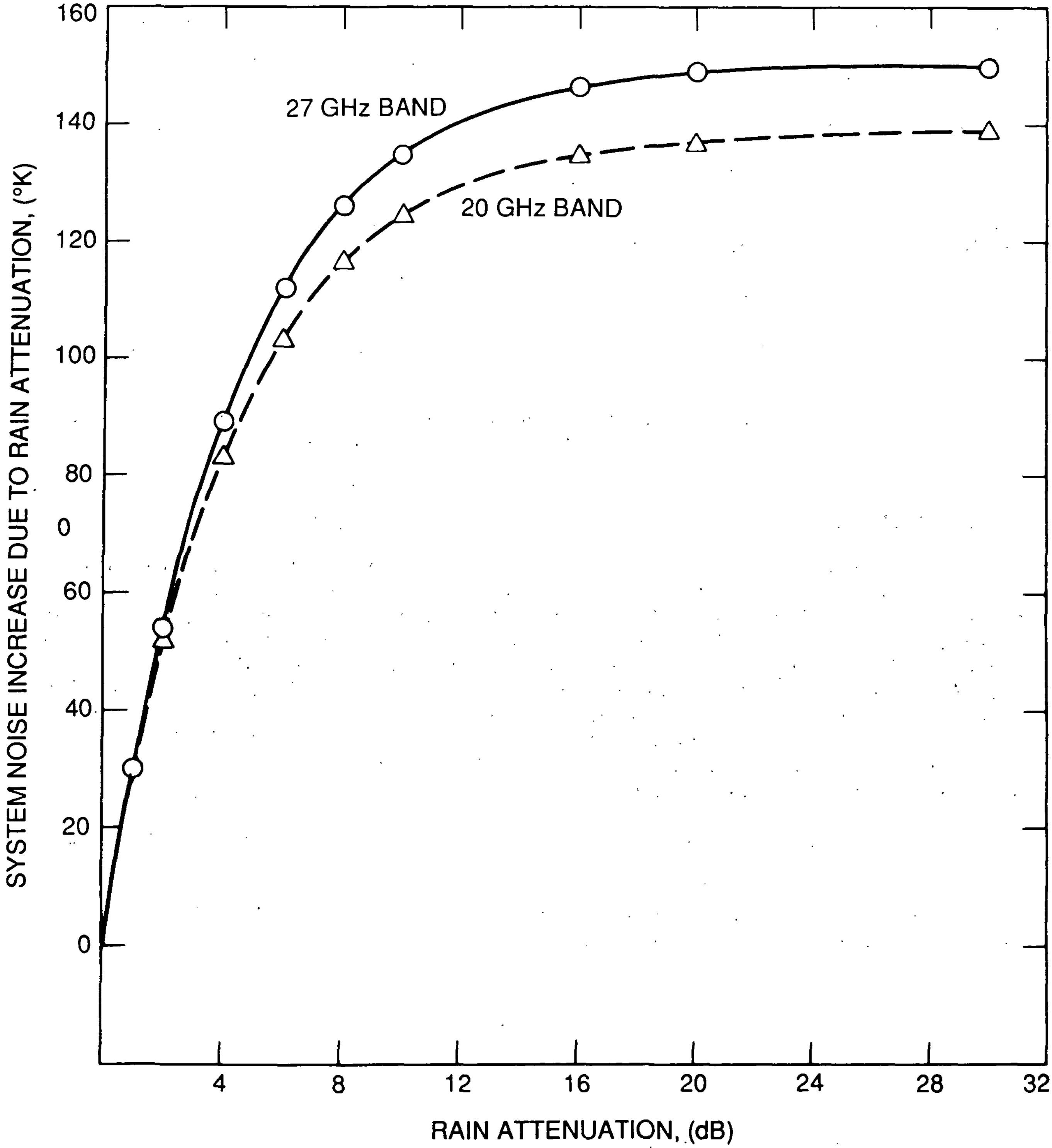

Figure 6. System Noise Increase Due Rain Attenuation

A typical sensitivity calculation for Dicke radiometer is shown below:

LNA maximum noise figure = 8-dB	$T_R \simeq 1550°K$ (max)
Sky noise temperature	$T_S \simeq 50°K$
RF Bandwidth	$B = 10$ MHz
Integration time	$\tau = 1$ sec
Sensitivity via (4)	$\Delta T_{rms} \simeq 1°K$

The proposed radiometer is a hybrid version of Dicke Switch and total power radiometer, hence, the sensitivity figure calculated above will be in the range of 0.5 to 1°K.

4.5 Example Link Calculations

We now perform some example link calculations using the concept of a common antenna, feed, and LNA for both 27 GHz and 20 GHz bands beacons as follows:

Parameters	Values	
Frequency band (GHz)	27.5	20
Common Antenna Size (m)	1	1
Antenna Efficiency (%)	55	60
Antenna Gain (dB)	46.5	44.2
Beam Width at -3 dB points (degree)	0.76	1.05
Beacon antenna gain over full CONUS (dBi)	26	26
Nominal beacon RF output (dBm)	20	23
Nominal beacon EIRP (dBw)	16	19
Path Loss at 30° elevation (dB)	213	210
Modulation Loss (dB)	-	2.3
System Losses including Modulation Loss (dB)	3.7	5.8
Max Dry Weather System Noise Temperature with 8-dB NF LNA (°K)	1750	1750
Dry Weather Receive G/T (dB/K) worst case	14.1	11.8
Boltzmann's Constant (dBw/K-Hz)	-228.6	-228.6
Receive Carrier-to-Noise Density, C/N_o (dB-Hz)	42	43.6
C/N in 10 Hz bandwidth (dB)	32	33.6
C/N Threshold Level (dB)	10	10
Dynamic range (margin over threshold) (dB)	22	23.6

Therefore, with a 1-m antenna, common feed and a worst case 8-dB noise figure LNA, the RF terminal will provide in excess of 20-dB dynamic range at both frequency bands. With 4-5 dB noise figure LNAs the dynamic range will be well in excess of 20-dB.

5. Hardware Design Considerations

ACTS beacon receive terminal design will perhaps be similar to the design of Olympus program [7]. However, logistically and technically, there are some differences [8, 9] which must be taken into consideration. In the Olympus program there are three beacons (12, 20, and 30 GHz bands) and three

separate antennas which simplified the RF system design. Economically, three separate antennas were perhaps justified for the Olympus experiment because only one experimenter was supported by NASA/JPL. On the other hand, a large number of participants (8-10) are envisioned in the ACTS propagation study. Therefore, two sets of antennas, and RF assemblies are not desirable economically and logistically. As a result, we examine two approaches as follows:

- Preferred Approach - Common antenna, dual polarized feed and two separate LNAs as shown in Figure 7.
- Alternate Approach - Two separate antennas and separate RF subsystems as shown in Figure 8 where the polarization of the 20 GHz terminal feed will be manually adjusted in the event the down-link beacon polarization is changed.

These two approaches are compared below:

Item	Common Antenna	Two Antennas
Antenna Cost	$XK	$2XK
Feed Cost	$YK	Nominal
(Antenna + Feed) Cost	$(X+Y)K	$2XK
Polarization Change	None	Yes
Operational Logistic	Simple	Difficult

Items mentioned above will be examined during the prototype development phase and the optimal design will be chosen for the manufacturing phase.

The proposed beacon receive terminal is comprised of three subsystems as follows:

- RF Subsystem - Out Door Unit (ODU), comprising the antenna, feed, radiometer, LNA and First IF Output (refer Figs. 7 and 8).
- IF Subsystem - In Door Unit (IDU), comprising second IF stage and distribution panel (refer Fig. 9).
- Fade detection unit comprising the digital signal processor and the computer interface unit which is discussed elsewhere.

5.1 RF Subsystem - Out Door Unit (ODU)

Two RF Subsystem (ODU) baseline block diagrams are shown in Figs. 7 and 8.

5.1.1 Antenna Functional Requirements

Size	1.0 m to 1.2 m
Type	Offset-fed or Cassegrain
Mount	Az/El
Feed Configuration	Dual Polarized

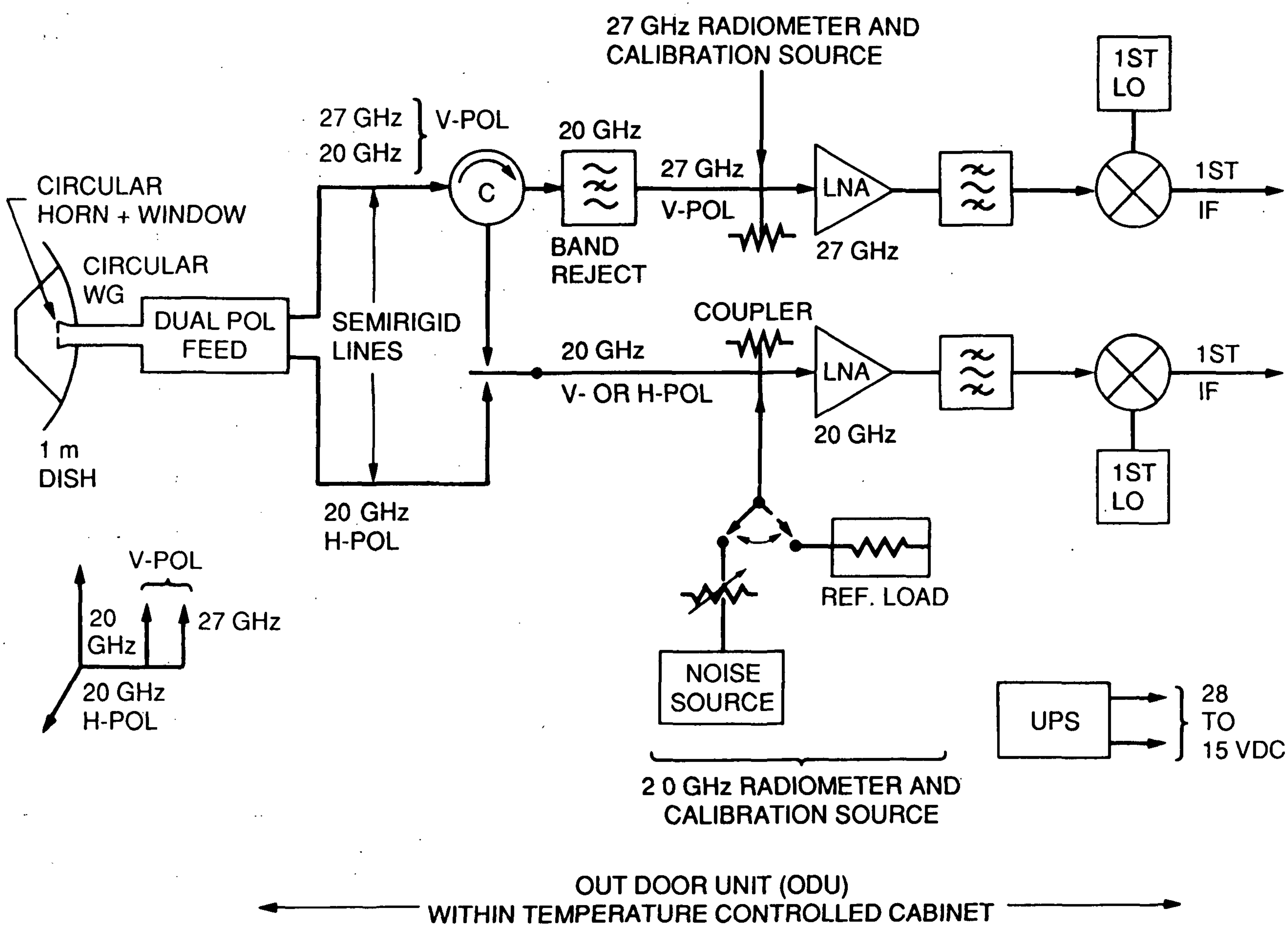

Figure 7. Scheme-1 Common Antenna: ACTS Beacon Receive RF Subsystem-Out Door Unit (ODU)

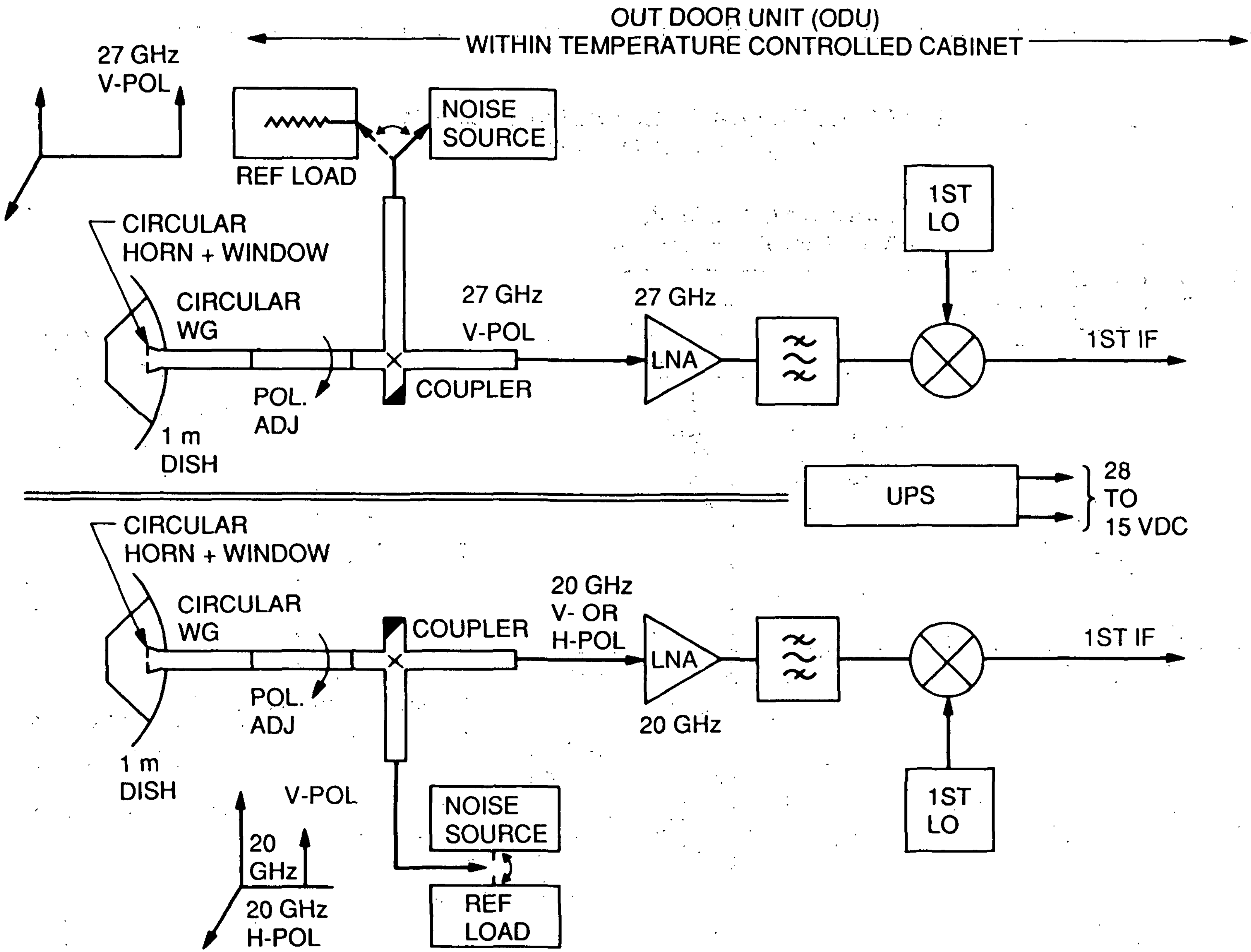

Figure 8. Scheme II Separate Antennas: ACTS Beacon Receive RF Subsystem-Out Door Unit (ODU)

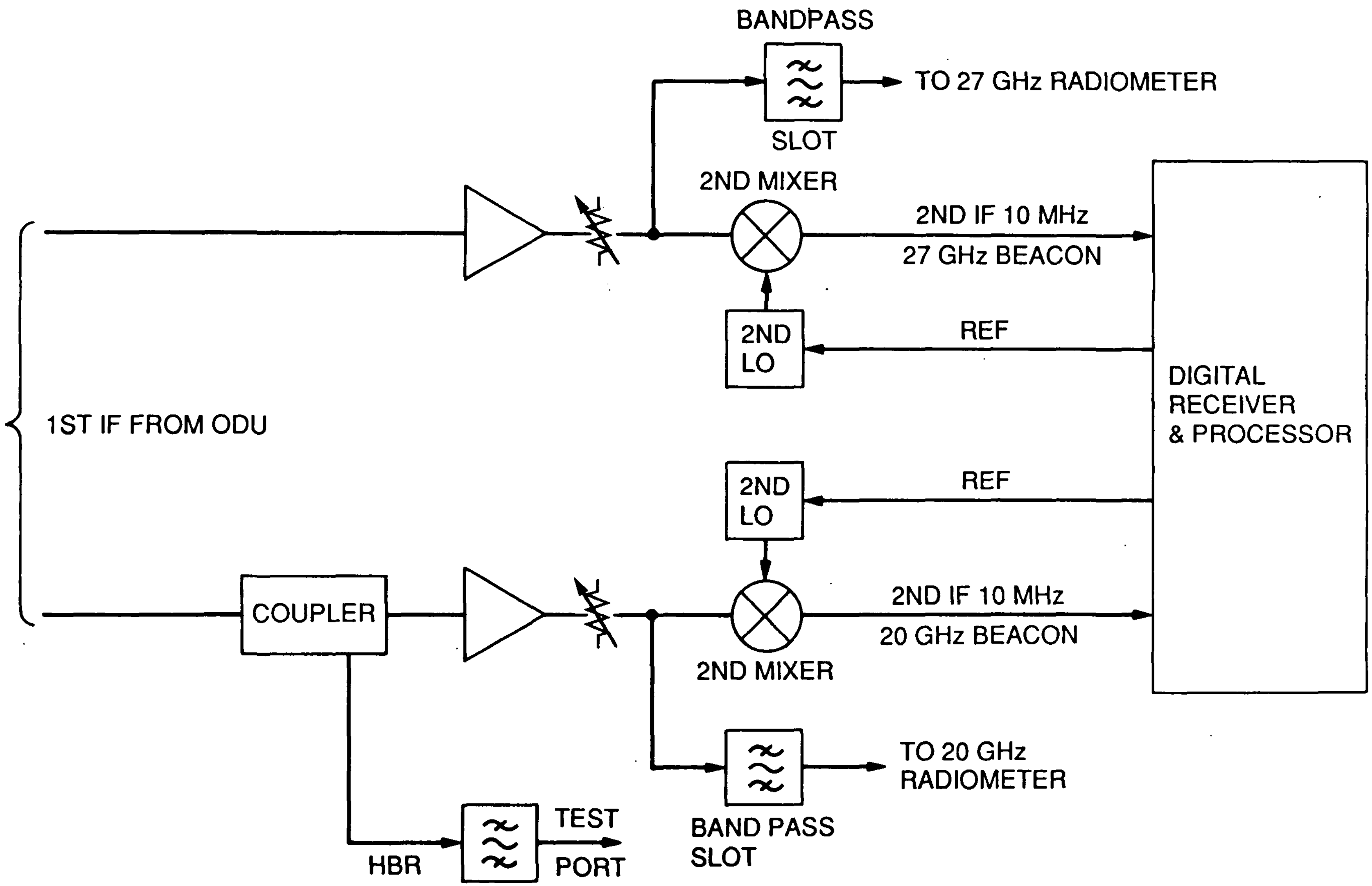

Figure 9. ACTS Beacon Receive IF Subsystem - In Door Unit IDU

Anti-Ice	Optional
Polarization	Orthogonal linear, mechanically adjustable (to 90°)
Receive Gain 1-m at 27.5 GHz	46.5 dBi
at 20 GHz	44.2 dBi
Cross-pol isolation	>25 dB
Waveguide interface	Circular (size TBD)
Operating temperature	-40° to +50°C
Operating wind speed	50 mph with 70 mph gusts
Survival wind speed	125 mph

5.1.2 Common Feed Unit

The principle of electric field distribution in a circular waveguide is utilized in separating two sets of orthogonal linear polarized signals [10] as shown in 10(a). The circular section of the feed excites both vertically polarized beacons when present in such a way that the TE_{11} Field vectors are perpendicular to the thin metallic septum (for initial alignment of the feed, the metal septum can be used as a reference plane) which transmits these vectors unperturbed to be coupled to the rectangular waveguide via a linear taper (circular-to-rectangular waveguide). The outputs are separated by a circulator and a 20 GHz band reject filter as shown in Fig. 7. Now if a coupling slot is cut across the broad side of a rectangular-circular waveguide junction as shown by the cross-sectional view (refer Fig. 10(b)) then the horizontally polarized beacon signal vector at 20.195 GHz when present will be coupled in the side rectangular waveguide exciting a TE_{10} mode. The septum will act as a reflector to the horizontal polarized vector. A mechanical switch will select the V- or H-Pol 20 GHz beacon as needed.

The slot dimensions, length (ℓ) and width (w) can be calculated [10] as follows:

$$\ell = \frac{\lambda o}{2} + 0.273 \text{ w}$$

or

$$1 = \frac{\lambda o}{2\ell} + 0.273 \left(\frac{w}{\ell}\right) \qquad (5)$$

where

λ_o = Free space wavelength at 20.195 GHz
(w/ℓ) ratio ≤ 0.11

Thickness of the slot should not exceed (w/2)

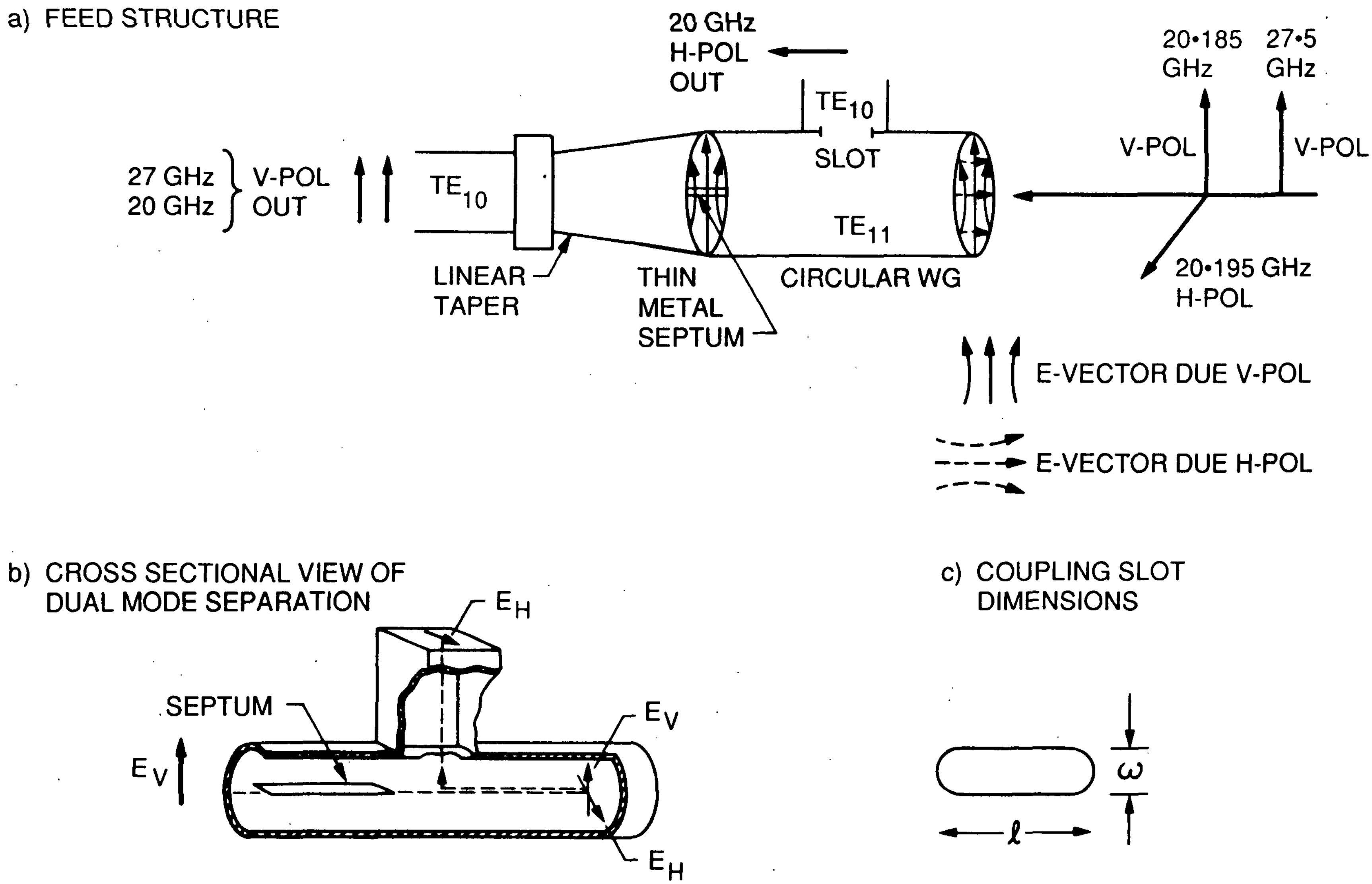

Figure 10. Common Feed Structure

5.1.3 LNA Characteristics

Typical characteristics of commercial LNAs are shown below:

Frequency Band	28 GHz	20 GHz
Gain	30 dB	30 dB
Noise Figure	4-dB	3.5 dB
Power Output @ 1-dB Compression	+10 dBm	+6 dBm
Gain Flatness	±0.5 dB	±0.75 dB
VSWR (In and Out)	2:1	2:1
Power Consumption	5.4-w @ +15 VDC	4.5-w @ +15 VDC
Operating Temperature	0-50°C	0-50°C
Connector	WR 28 (I/O)	SMA (I/O)

5.1.4 Excess Noise Source for Radiometer

As discussed before, a radiometer provision is essential to measure the excess noise temperature and to calibrate the system from slowly varying fluctuations of the system parameters such as gain/bandwidth of the receiver. The radiometer can be total power type or Dicke-switch type. A broadband saturated diode type noise source is provided with a precision attenuator for noise level setting which can be switched electronically by a motor drive. A reference ambient or cooled waveguide load or a combination of both can be provided for the noise source calibration at a regular interval.

5.1.5 First Down-Converter

After noise injection, the beacon signal in the presence of link noise and additional injected noise are split into two separate beacon paths in the Common Antenna Scheme as shown in Fig. 7. In the two-antenna scheme the RF paths are separate as shown in Fig. 8. The up-link fade beacon is filtered through a narrowband bandpass filter (±100 MHz) to eliminate spurious. On the other hand, the down-link beacon/s is filtered through a reasonably wideband filter, ±500 MHz bandwidth in order to accommodate the communication carrier band/s for experimental purposes to be discussed. Temperature controlled crystal oscillators provide two LO sources.

Functional requirements of the first down converter are shown below:

Input Level	-80 ±6 to -110 ±6 dBm
Output Level	-20 ±6 to -50 ±6 dBm
Nominal Frequency	TBD
Bandwidth	±500 MHz
Output Impedance	50 ohms
Return Loss	> 15 dB
Image Rejection	> 45 dB
Nominal LO Frequencies	TBD
Phase Noise	-80 dBC/Hz @ 10 KHz

5.2 IF Subsystem - In Door Unit (IDU)

The IF Subsystem as shown in Fig. 9 essentially provides two channel outputs for each receive beacon path. One channel feeds the radiometer and the second channel feeds the link fade detector. The nominal frequency of the second IF is 10 MHz. Two band pass slots are inserted in the radiometer path prior to the second mixer. The bandwidth of these slots determine the predetection bandwidth of the radiometer (B in equation 4).

The 20 GHz beacon path has an additional port which can allow the communication carrier say the HBR to be used for additional tests. An example of the additional test could be an attenuation measurement of the unmodulated HBR carrier power via the mechanically steered spot beam in region/s beyond CONUS coverage say Alaska, Polar Region or Hawaii where the beacon signal strength is very low.

6. Acknowledgements

Acknowledgement is made to R. Hughes of JPL and members of the EE Department of Virginia Polytechnique Institute for many useful discussions.

7. Conclusions

ACTS propagation experimenters' terminal hardware design issues have been identified and a practical design plan and specifications have been outlined.

8. References

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